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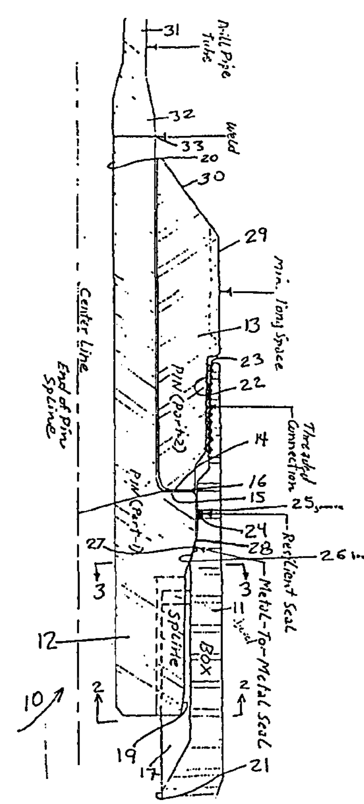
(54) Title: ROTATIONALLY LOCKED TOOL JOINT FOR CONNECTING DRILL PIPE SECTIONS TOGETHER

(57) Abstract

The ends of drill pipe sections are connected together with a connection that mechanically locks the sections against relative rotational movement. The connection includes a pin member (12) on the end of one of the tubular sections that is received within a box member (11) formed at the end of an adjoining pipe section. The two members (11, 12) have a splined structure (17, 18) that meshes to lock the adjoined connections against relative rotary movement. The two sections are held together axially by a threaded lock collar (13) threadedly engaged within the box member (11) of the connection. Threaded engagement of the collar (13) into the box (11) draws a pin shoulder (15) into a tapered metal–to–metal seal (28) within the box to seal the annular area between the mated connection components. A secondary, annular elastomeric seal member (24) may also be disposed in the overlapping pin (12) and box (11) area.



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ROTATIONALLY LOCKED TOOL JOINT FOR CONNECTING DRILL PIPE SECTIONS TOGETHER

Background of the Invention

Field of the Invention

The present invention relates to connectors for assembling the ends of tubular bodies to each other. More specifically, the present invention relates to a connector for assembling the ends of drill pipe tubes together to form an elongate drill pipe string.

Description of the Prior Art

Conventional drill pipe sections referred to as "joints" have a pin connector at one end of the joint and a box connector at the opposite end of the joint. The box is internally threaded, and the pin is externally threaded. Pipe joints are secured to each other, or made up, by inserting the pin of one joint into the box of an adjacent joint and rotating one of the joints, usually in a clockwise direction, to engage the threads. The pin advances into the box until an annular metal shoulder at the base of the pin threads is engaged with an annular metal shoulder at the face of the box. The connection is referred to as a rotary shouldered connection. The engaged shoulders provide a metal-to-metal seal in the rotary shouldered connection. The engaged threads hold the connection together and maintain a bearing pressure on the metal-to-metal seals.

The sealing capacity of the engaged metal-to-metal seals in a rotary shouldered connection is determined by the bearing pressure of the seals against each other. The bearing pressure, in turn, is determined by the thread design and the amount of torque applied in securing the pin and box together. Depending upon the size and type of connection being made up, it is not uncommon to require makeup torques in the range of 50,000 ft-lbs. and more. Some recent tool joint connection designs employ the thread interference to provide a pressure seal rather than shouldered metal seal surfaces. These new connections may require the application of high levels of torque for several revolutions of the connection, in which case heavy-duty, expensive rotary power tongs are employed to make up the connection.

Most rotary drilling operations require clockwise rotation of the drill string and the associated bottom hole assembly carried at the bottom of the drill string. This rotation, referred to as right-hand rotation, tends to apply a clockwise torque to each of the connections in the string, which tends to increase the engagement between the connections. In some circumstances, it may be necessary to rotate the drill string in a counterclockwise direction. Such left-hand rotation must be carefully applied and may only be performed at very low torque levels lest the right-hand threaded connections in the assembly become unthreaded, permitting the string to separate.

Modern drilling techniques require that some well bores be diverted from the vertical to angular deviations as great as 90° or greater. As the drill string bends around these curvatures, the sides of the drill string connections at the inside of the curve are stressed in compression, and the sides of the connection at the outer edge of the curve are somewhat relieved of compressive stress. The result is that a differential in the forces acting across the drill pipe connection is produced as the drill string bends around the curve in a deviated well bore. When the drill string is rotated around the curve, the area of increased and decreased stress travels around the connection each revolution of the drill pipe. These alternating stress forces can induce fatigue failures in the drill pipe connection.

Summary of the Invention

The connection of the present invention mechanically locks one drill pipe joint to another so that rotary motion between the two joints is precluded. The rotary lock is provided by non-threaded, mechanically interfering surfaces carried at the ends of the adjoined pipe connections. In the preferred form, the rotary interfering structure is a spline connection. One of the connected members is a pin, and the adjoining connection member is a box. The pin is provided with an enlarged, annular shoulder that engages an annular seat in the box. A lock sleeve carried over the pin is provided with threads that engage threads formed within the box. Threading the sleeve into the box draws the enlarged pin shoulder into the box where the shoulder is seated against the annular box seat to provide a metal-to-metal shouldering seal. The torque required to fully mate the sleeve and box and to obtain the desired metal-to-metal pressure seal is very low compared with that required for securing conventional drill pipe connections.

The engaged metal seal surfaces between the pin and the box of the present invention are tapered relative to the common axis of the joined pin and box components. The engaged surfaces form an annular, metal-to-metal, frustoconical sealing area that maintains a pressure seal between the inside and the outside of the connection during the cyclic stresses of rotation around curved bore hole section. The tapered configuration of the metal-to-metal seal is optimized to minimize the effect of the alternating increasing and decreasing stress force applications on the connection as it is being rotated in a deviated well bore without unduly increasing the radial size of the connection.

The mechanical spline engagement between the pin and box prevents relative rotation of the connected drill pipe joints. The drill string made up with these connections thus may be rotated either to the left or to the right without concern for unthreading the connection. The metal-to-metal seal is carried within the box at a protected location where it is shielded from the effects of contact with the surrounding bore hole wall.

A secondary, annular, elastomeric seal is provided between the pin and box to provide additional sealing between the engaged components. In the preferred form of the invention, the resilient seal is carried in a groove extending annularly within the area of the tapered metal seal area of the pin.

The lock collar of the invention may be applied to the pin connector after the tool joint has been welded onto the drill tube section or after the tube is upset to form the tool joint configuration. In the latter situation, the tool joint may be formed by upsetting the tube end to eliminate the need for welding a tool joint to the tube. As a further advantage, the multiple-piece lock sleeve may be removed as required to recondition or repair the sleeve.

The threads of the lock collar and box are preferably left-handed to prevent a back-off of the connection when the drill string is rotated to the right. The outside diameter of the collar is smaller than the outside diameter of the box to minimize the effects of drag on the collar as it is rotated in the well bore.

An adapter is provided for attaching a drill string made up with connections of the present invention to a conventional top drive system. The pin component of the connection of the present invention is provided at one end of the adapter, and a conventional rotary shouldered pin connection is provided at the adapter's opposite end.

The conventional rotary shouldered pin connection mates with the box connection at the drive end of a conventional top drive. If desired, the adapter may also be equipped with the multiple-piece lock collar.

From the foregoing, it will be appreciated that a primary object of the present invention is to provide a connector for securing together the ends of drill pipe sections whereby a drill string assembled from such sections may be rotated to the left or the right without danger of disengaging the connection.

Another object of the present invention is to provide a connector for drill pipe joints that can be employed in a drill string that extends through a curved well bore section and rotated therein without causing fatigue damage to the components of the connector.

Yet another object of the present invention is to provide a connector that may be assembled using a relatively low power torque wrench to eliminate the need for use of a large, high torque wrenching device for securing the connectors together.

It is also an object of the present invention to provide a drill pipe connector having a wrench area that is smaller in diameter than the remainder of the connection to reduce the drag of the wrench area on the well bore wall during rotation of the drill string.

An important object of the present invention is to provide a tapered metal-to-metal seal in a pin and box connection whereby the connection can be alternately stressed at different points along said seal without causing excessive fatigue in the connection.

Yet another object of the present invention is to provide a connection for drill pipe joints that is inexpensive to fabricate and repair and that can be easily made up with low torque equipment and that can be rotated within a curved well bore without excessive loading of the connection.

An object of the present invention is to provide a drill string connector having a lock collar with left-hand threads whereby the right-hand rotation of the connector within a well bore does not tend to unthread the lock collar from the connector.

The foregoing, as well as other, objects, features, and advantages of the present invention may be more readily understood and appreciated by reference to the following figures, specification, and claims.

Brief Description of the Drawings

Fig. 1 is a vertical quarter-sectional view of a connector of the present invention;

Fig. 2 is a horizontal cross-sectional view taken along the line 2-2 of Fig. 1 illustrating details in the spline engagement of the present invention;

Fig. 3 is a view taken along the line 3-3 of Fig. 1;

Fig. 4 is an isometric view of a pin member of the present invention;

Fig. 5 is an enlarged detail of the tapered metal-to-metal seal and spline area of the present invention;

Fig. 6 is an enlarged, partial sectional view illustrating details in the resilient sealing element of the present invention;

Fig. 7 is a modified form of the pin of the present invention;

Fig. 8 is a modified form of the pin section of the present invention having a resilient seal in the tapered metal-to-metal seal area of the pin;

Fig. 9 is a vertical, quarter-sectional view illustrating a modified form of the connection of the present invention;

Fig. 10 is a vertical elevation of an adapter subassembly employed in connecting the drill string and connectors of the present invention to a top drive assembly;

Fig. 11 is a vertical quarter-sectional view illustrating a modified form of the connector of the present invention with a multiple-part locking collar;

Fig. 12 is a full horizontal cross-section taken along the line 12-12 of Fig. 11;

Fig. 13 is a full horizontal cross-sectional view illustrating a modified form of the connector of the present invention employing multiple locking collar segments;

Fig. 14 is a vertical elevation illustrating a modified top drive subassembly of the present invention;

Fig. 15 is a vertical sectional view illustrating a connector of the present invention designating critical dimensions of the connector;

Fig. 16 is a horizontal cross-sectional view taken along the line 16-16 of Fig. 15;

Figs. 17A, 17B, and 17C are stress analysis illustrations, in quarter-sectional views, depicting an initial preload producing 0.010-inch interference in the seals of a connector of the present invention;

Figs. 18A, 18B, and 18C are stress analysis illustrations, in quarter-sectional views, depicting stress distributions over the connector of Figs. 17A, 17B, and 17C with an applied tension load of 600,000 lbs.;

Figs. 19A, 19B, and 19C are stress analysis illustrations, in quarter-sectional views, depicting stress distribution over the connector depicted in Figs. 17A, 17B, and 17C with a tension load of 666,536 lbs.;

Figs. 20A, 20B, and 20C are stress analysis illustrations, in quarter-sectional views, depicting an initial preload producing 0.010-inch interference in the seals of a connection of the present invention;

Figs. 21A, 21B, and 21C are stress analysis illustrations, in quarter-sectional views, depicting stress distribution over the connection of Figs. 20A, 20B, and 20C having a tension loading of 733,190 lbs.;

Figs. 22A, 22B, and 22C are stress analysis illustrations, in quarter-sectional views, depicting stress distribution over a connection of the present invention depicting an initial preload producing 0.010-inch interference in the seals of a connection of the present invention;

Figs. 23A, 23B, and 23C are stress analysis illustrations, in quarter-sectional views, depicting the connector of Figs. 22A, 22B, and 22C with an applied tension loading of 844,244 lbs; and

Fig. 24 is a chart illustrating various pipe dimensions and ratings for different pipe connectors of the present invention.

Description of the Preferred Embodiments

The connection of the present invention is indicated generally at 10 in Fig. 1. The connection is used to connect the ends of tubular pipe sections used for a drill string in drilling wells. The connection comprises a box member 11 and a pin member 12. The pin member includes an externally threaded lock collar 13. An annular end shoulder surface 14 at the nose of the lock collar 13 engages a correspondingly configured annular torque shoulder 15 formed on the pin member. The surfaces 14 and 15 engage to form an axial bearing force surface indicated at 16.

Circumferentially spaced, axially extending rib sections 17 project radially inwardly from the internal surface of the box 11. As may best be noted by joint reference

to Figs. 1-3, the ribs 17 are engaged within axially extending, circumferentially spaced recesses 18 formed along the external circumferential surface of the base of pin 12. The recesses 18 and rib sections 17 cooperate to provide a rotation lock in the form of a spline connection that prevents relative rotary movement between the pin 12 and the surrounding box 11 while permitting relative axial movement of the pin and box components during the assembly and disassembly of the connection.

The nose of the pin 12 is tapered, as indicated at 19, to assist in guiding the pin recesses over the box ribs when the pin is stabbed into the box during the initial assembly of the connection. A central opening 20 extends axially through the center of the pin section and communicates with a central opening 21 extending axially through the box section 11. As will be understood, the openings 20 and 21 conduct drilling fluids through the drill string formed by multiple pipe sections connected end to end with connectors such as the connector 10.

In use, the connector 10 of the present invention is employed to secure together multiple, similar tubular drill pipe sections ("joints") to form an elongate drill string. Each drill pipe joint is provided with a pin member at one axial end and a box member at the opposite axial end. The combined string is formed by engaging the pin member of one joint with the box member of an adjacent joint. Engagement of the rotation lock permits the drill string to be rotated in a clockwise or counterclockwise direction without danger of unthreading the connections in the string. The lock collar design of the connection also permits the connection to be secured in a leakproof connection with much smaller makeup torques than required for conventional rotary shouldered tool joint connections.

The lock collar 13 is provided with external threads 22 that mate with internally formed threads 23 in the box 11. An elastomeric seal ring 24 carried in an annular groove 25 formed in the box 11 engages the external surface of the pin section 12 to provide a resilient seal between the pin and box sections. A frustoconical, internal shoulder seat 26 formed along the surface of the box 11 engages a frustoconical, radially extending, external shoulder 27 formed along the surface of the pin 12 to provide a shouldering, metal-to-metal seal 28.

The connection 10 is assembled by lowering the pin section 12 into the box section 11, causing the splined arrangement of ribs 17 and recesses 18 to meet and mesh.

With the spline engaged, the pin connection is advanced into the box until the conical surfaces 26 and 27 engage in the metal-to-metal seal 28. During this assembly process, the pin nose taper 19 assists in directing the end of the pin past the seal surface 27 and into meshing engagement with the box.

Once the pin is seated within the box, the collar 13 may be rotated to cause engagement between the threads 22 and 23. In the preferred form of the invention, threads 22 and 23 are "left-hand" threads that are engaged by rotating the collar 13 in a counterclockwise direction. The outer surface of the collar 13 between the threads 22 and the upper collar end provides a wrench area 29 that is engageable by a power wrench, or rotary power tong (not illustrated), employed to apply torque to the collar when the connection is being secured or released. The area 29 is provided with sufficient axial length to receive the tong jaws. The diameter of the wrench area 29 is preferably less than that of the box 11 to minimize dragging of the collar on the well bore wall during rotary drilling. The upper end of the lock collar 13 has an annular taper surface 30 employed to deflect the connection 10 from internal well bore obstructions as the drill string is retrieved to the well surface. The connection 10 is secured to a tubular drill string body 31 having an upset area 32. The tube 31 is welded at 33 with the pin body 12. The box 11 is secured to a similar tubular drill string body (not illustrated) that carries a pin connector at its opposite end.

Fig. 4 is a perspective view of the pin member of the connection of the present invention. The pin member includes the collar 13 that is axially and rotatably movable over the underlying tubular body of the pin connection 12.

Fig. 5 illustrates a modified form of the invention illustrating a resilient seal assembly, indicated generally at 34, employed in combination with the metal-to-metal seal 28. Fig. 6 is an enlarged, detail illustration of the resilient seal 34. The seal assembly 34 is carried in an annular groove 35 extending circumferentially within the metal-to-metal seal area of the pin connection 12. The angle of the seat 26 relative to the common central axis of the connection formed by the engaged pin 12 and box 13 is indicated at A. In the illustrated embodiment, the angle A is approximately 30°. The metal-to-metal seal surface 28 is illustrated as being formed by the overlapping of the metal seat surface 26 and the metal surface of the conical shoulder 27. In the illustrated

embodiment, the two conical surfaces engage to produce a compression or interference of 0.010 inches.

The assembly 34 is a two-part seal having an elastomeric, O-ring seal member 36 contained within a surrounding annular contact seal ring 37. The seal assembly 34 provides an annular, resilient seal contact surface 38 to effect a pressure seal between the conical metal seal surface of the pin 12 and the conical, internal metal seat 26 of the box connection 11. The illustrated resilient seal assembly 34 cooperates with the metal-to-metal seal 28 to prevent the passage of fluids between the engaged box 11 and pin 12.

The contact seal ring 37 may advantageously be constructed of a material such as a glass-filled Teflon composition or other suitable material. The elastomeric O-ring seal 36 may be constructed of a resilient fluorocarbon compound having a desirable elastomeric characteristic. In operation, the seal ring 37 is forced radially outwardly by the O-ring 36 to provide a firm, resilient bearing pressure against the seat 26. The material of the seal ring 37 withstands physical contact and wear against the metal surface of the seat 26 while the O-ring seal member 36 provides a resilient force urging the seal ring 37 into firm sealing engagement with the seat 26.

The size of the angle A is an important factor in the operation of the connection of the present invention. If the angle A is too small, the induced radial expansion forces acting on the box 11 can undesirably stress the box, causing damage or even permitting separation of the pin and box connection. While the damaging effects of the radial expansion may be reduced by increasing the thickness of the wall of the box 11, it is desirable to keep the external diameter of the box 11 as small as possible to optimize the clearance between the connection and the surrounding well bore of the well being drilled. The angle has a preferred range of from 5° to 80°.

Another critical area of the connection is the cross-sectional area at 39 of the box. The area 39 occurs at the last engaged thread connection between the lock collar 13 and the box 11. The forces in the engaged connection of the present invention acting at the critical area 39 include the preload forces imposed by threadedly advancing the collar shoulder 14 against the pin shoulder 15. The preload force must be sufficient to prevent the metal-to-metal seal from failing as the pin and box are being pulled apart by the forces imposed by the drilling motion, the string weight, and the rig lifting forces. These

forces combine to impose a separation force at the critical box area that can force the box to fail when the maximum force loads are exceeded.

The force exerted by advancing the collar 13 against the bearing surface 15 is employed to impose a preload on the metal-to-metal seal 28 that maintains a pressure seal between the pin and box. The total contact surface of engagement in the metal-to-metal seal 28 is desirably held to the smallest area practical to achieve the desired sealing pressure. The various forces acting on the connection are related in that the greater the bearing surface area of the metal-to-metal seal, the greater the preload force required to obtain a desired sealing pressure, which in turn imposes the need for a larger, stronger box to prevent failure of the box. Selection of the angle A and the preload sealing force is made with consideration for the anticipated drilling forces to ensure that the connection is sufficiently strong to withstand the expected drilling application while maintaining the desired seal between the pin and box. The effective sealing area occurring along the tapered metal-to-metal seal 28 is calculated by determining the effective preload force required for obtaining a seal in a hypothetical, 90° metal-to-metal seal surface. As the angle A decreases toward 0°, the force required to obtain a desired sealing pressure becomes greater. Accordingly, the larger the angle A, the less preload force required to obtain the desired sealing pressure for a given metal-to-metal seal area.

Fig. 7 illustrates a modified pin member 45 in which an annular, elastomeric O-ring seal 46 is carried in a groove 47 extending annularly about the pin 45. The modified pin 45 includes splined recesses 48 and an annular, frustoconical metal-to-metal shoulder 49 adapted to engage and seal with the seat of an adjoining box connection (not illustrated). The seal ring 46 may be constructed in a manner similar to that illustrated in Fig. 6 or may comprise a single element, O-ring seal assembly constructed of a suitable elastomeric material. The pin member connection 45 provides an elastomeric seal between the outer cylindrical area of the pin body and the internal, cylindrical wall of the connection box.

Fig. 8 illustrates another modified form of the pin member of the connection of the present invention, indicated generally at 50. The modified pin member 50 includes an annular, elastomeric O-ring seal 51 carried on the metal-to-metal seal surface 52 of the pin. As with the embodiment of Fig. 5, the annular seal ring 51 is adapted to engage and seat with the tapered frustoconical seat of the box (not illustrated) to provide an

elastomeric seal that cooperates with the metal-to-metal seal formed by the frustoconical, external metal-to-metal seal 52.

Fig. 9 illustrates a modified form of the connection of the present invention indicated generally at 60. The connection 60 includes an axially extending pin section 61 and an axially extending box section 62. A locking collar 63 is employed to secure the pin and box connections firmly together to prevent relative axial movement between the pin and box. Threads 64 on the collar 63 mate with threads 65 on the box 62, whereby rotation of the collar into the box advances the pin section 61 into the box to form a metal-to-metal seal at 67. An annular, elastomeric seal ring 68 carried in an annular groove 69 in the base of the box 62 provides a secondary, resilient seal between the pin and box connection.

A rotation lock is provided to prevent relative rotation between the engaged pin and box. The rotation lock is provided by interlocking engagement of the pin end projections 70 extending from the base of the pin section 61 into box recesses 71 formed in the base of the box 62.

Engagement of the pin 61 in the box 62 provides for a pressure seal between the pin connector section 61 into the box connection 62. The connection 60 also provides the required mechanical connection between the pin and box to retain the two components together. As with the earlier described designs, the lock collar 63 is employed to apply a preload to the metal-to-metal seal area 67 and to trap the pin within the box to prevent axial separation of the connection. The engagement of the projections 70 and recesses 71 provide a rotation lock that prevents relative rotation between the pin section 61 and the box section 62 without imposing any of the forces of rotation in the threaded components of the connector. The lock collar 63 is made up into the box 62 by rotary motion applied with a power tong or other suitable device. The threads 64 and 65 are preferably "left-hand threads" to prevent the collar 63 from being backed out of the box when the drill string assembly connected by the connection 16 is being rotated in a normal clockwise direction, as employed during conventional drilling procedures. The outside diameter of the lock collar 63 is also preferably smaller than the outside diameter of the box section 62 in the engaged thread area to minimize the effects of drag on the collar 63 as the drill string is rotated.

Fig. 10 illustrates a top drive adapter, indicated generally at 80, employed to cross over between the connection of a conventional top drive and the connector of the present invention. As is well known in the art, a top drive is a system for powering a drill string and is used to replace the function of a rotary table in a standard drilling rig. The top drive provides rotary and lifting movement through the length of the drilling derrick. The drive motor in a top drive assembly is movable from the floor level to the top of the derrick along a vertical guide system. Connection of the top drive to a drill string of the present invention requires crossing a conventional pin connector to a box connector of the present invention. The adapter 80 employs a conventional rotary shouldered pin connection 81 to mate with the box at the end of a conventional top-drive output shaft (not illustrated). The tool joint 81 is welded to a tubular connecting body 82 having a pin member 83 of the present invention. A locking collar 84 extending around the tubular connection section 82 is movable axially between the tool joint 81 and the pin section 83. The collar 84 is provided with pin threads 85 that are adapted to mate and engage with the box threads at the top end of a drill string secured together with pipe sections having the connections of the present invention.

In use, the pin section 83 is introduced into a box such as illustrated in Fig. 1. The collar 84 is then advanced over the tube 82 until the threads 85 are engaged with the box threads and the collar is then rotated to engage the threads 85 with the threads in the box. The form of the pin assembly 82 illustrated in Fig. 10 includes an annular, elastomeric seal ring 85 carried in a groove formed along the external, tapered metal-to-metal surface 87 of the pin section. Spline grooves 88 are provided at the base of the adapter, which in other respects is also similar to the pin sections described with respect to the pin connections earlier described in other embodiments of the invention.

Engagement of the pin section of the adapter 80 to the box at the top of a drill string provides a connection similar to those described with reference to the embodiments of Figs. 1-9, to secure the top drive to the drill string. As with the other connections in the drill string, the threads 85 are "left-hand threads" so that the collar 84 is rotated in a counterclockwise direction to engage and preload the pin connection 83 with the annular seat in the box within which it is connected. Where high left-hand rotation torques are anticipated, the connection to the top drive may be clamped or otherwise fixed to prevent disengagement of the tool joint pin connection 81 from the top drive shaft.

The adapter imparts the vertical and rotational movement of a top drive to the drill string connected to the adapter. As with the embodiments of Figs. 1-9, rotation of the top drive connected to the upper end of the top drive adapter 80 is transmitted through the spline components 88 of the adapter to the drill string connected to the lower end of the adapter. The mechanical engagement of the collar 84 with the box of the drill string prevents relative axial movement between the adapter and the drill string so that the vertical movement of the top drive is also imparted to the drill string.

Fig. 11 illustrates yet another embodiment of the connector of the present invention indicated generally at 90. Corresponding components in the various embodiments described herein operate in a similar fashion. The embodiment of Fig. 11 includes a two-piece lock collar 91 that may be applied to the drill pipe body 92 after the pin section 93 has been upset to provide an enlarged area for the spline connection 94 and the locking shoulder 95. With joint reference to Figs. 11 and 12, the lock collar 91 is formed from two mating half-sleeves 96 and 97 that are held together by clamping rings 98 and 99. Four guide pins, such as guide pins 100 and 101 are employed to provide matching alignment of the two sleeve sections 96 and 97. Pins 101 and 100 may be permanently secured in one of the sleeve sections 96 or 97 and have a free end extending into a closely fitting, axially extending groove 102. Engagement of the pins 101 and 100 in the groove 102 places the two sleeve sections in proper alignment so that external threads 103 on the sleeve sections properly mate with each other and form a continuous pin thread configuration for mating threaded engagement with internal threads 104 formed within a box 105.

The clamp rings 98 and 99 may be formed of any suitable material that can secure the two lock collar sleeves together and hold them on the tube body of the pin connection 92 when the collar is not engaged in the box. The alignment pins 100 and 102 are not stressed structurally when the assembled sleeves are threaded into the box 105. The alignment pins thus need only have sufficient mechanical strength to maintain the alignment and relative position of the two sleeves around the pin tube 92 during the time that the lock collar is not engaged with the box. Similarly, the clamps rings 98 and 99 need only be sufficiently strong to hold the two sleeve sections in position about the pin tube 92 when the lock collar is not engaged in the threaded box.

The advantage of a lock collar constructed as illustrated in Fig. 12 is that the collar may be applied to the drill pipe section after the pin end of the drill pipe section has been upset or welded onto the drill pipe tube. This eliminates the need to position a continuous single piece locking collar over the tube before either end has been upset or before a pin or box tool joint is welded to the end of the pipe body. An additional advantage results when it is necessary to repair the lock collar 91. In the event the collar requires repair, it is only necessary to disengage the lock rings 98 and 99 to permit the collar to be removed and thereafter replaced with a repaired or new tube section locking collar. Where the locking collar is a single piece sleeve positioned on the drill pipe body before the tool joint is welded on or before the upset is formed at the end of the drill pipe tube, it is not practical to remove and replace a single piece lock collar.

Fig. 13 illustrates a modified form of the connector of the present invention indicated generally at 110. The connector 110 is similar to the connector illustrated in Fig. 12, except that the two mating lock collar sections 111 and 112 are welded together at their junctions 113 and 114. As with the embodiment of Fig. 12, the connector 110 may have the collar sections 111 and 112 applied to a pipe body 115 after the end of the pipe body has been upset or a tool joint has been welded to the tube. The collar, comprised of sections 111 and 112, may be removed from the pipe body 115 for replacement or repair by grinding out the welds 113 and 114 or by otherwise cutting the collar assembly open.

A modified form of the top drive adapter employed with the present invention is indicated generally at 120 in Fig. 14. The adapter 120 is similar to the adapter illustrated in Fig. 10 except that the lock collar 121 is assembled in two pieces held together by clamp rings 122 and 123. Guide pins (not illustrated) or other alignment mechanisms may also be employed in the embodiment 120 to provide proper matching of the threads formed on each of the two sections comprising the threaded lock collar 121. As with the lock collar embodiment described with reference to Fig. 13, the lock collar 121 may also be welded together rather than being secured by the lock rings 122 and 123. The same advantages as described with respect to drill pipe joints applies to a top drive adapter equipped with mating lock collar sections that may be applied after the ends of the adapter have been formed or secured to the tube body supporting the lock collar.

Fig. 15 is a vertical cross-section illustrating a connection of the present invention indicated generally at 125. The connection includes a pin section 126 engaged in a box section 127. A 30° tapered metal-to-metal seal 128 is formed between the pin and box sections. The pin and box are secured together by the threaded engagement of a lock collar 129 with the box 127. Threads 130 formed on the pin section 129 mate with threads 131 formed internally of the box 127. The threads 130 and 131 may preferably be of a PAC thread form, having a 0.75 inch per foot taper. The end of the pin section engages with the base of the box section to form a spline connection, indicated generally at 132. The spline may preferably be a fillet root, side fit configuration illustrated in detail in Fig. 16.

A finite element analysis of the connection 125 illustrated in Fig. 15 was performed for evaluation of the connection at the indicated diameters in Fig. 15. In Fig. 15, the OD min is the minimum tool joint outside diameter; ODtj is the tool joint outside diameter; PDt is the thread pitch diameter; ODp is the outside diameter; Dsh is the shoulder diameter; IDtj is the tool joint internal diameter; Do is the major external diameter; Dre is the minor external diameter; Di is the minor internal diameter; Dri is the major internal diameter; Lsh is the minimum shoulder length; Lt is the thread length; and Ls is the actual spline length in the area of the engaged spline members of the pin and box assembly.

In Fig. 16, PDs is the spline pitch diameter; p is the circular pitch; h is the depth of engagement; and t is the spline circular thickness.

Figs. 17A, 17B, and 17C are finite element stress analyses of a connection such as the connection of Figs. 15 and 16, except that the metal-to-metal seal 128 taper is 15° rather than 30°. The connection is a 7⅝-inch by 4⅞-inch JWSC connection with an interference of 0.010 inch between the pin and box sections of the metal-to-metal seal at the optimum makeup torque for this connection.

Fig. 17A illustrates a quarter-sectional view of the made-up connection with the different colorations indicating differing degrees of stress occurring at the area of coloration. Fig. 17B is an enlarged section of Fig. 17A, and Fig. 17C is an enlarged area of the connection section of the figures. The color code associated with the figures indicates the stresses induced in the connection when the tension imposed on the metal-to-metal seal area is at initial makeup. Stresses at a tension load of 600,000 lbs. are

illustrated in Figs. 18A, 18B, and 18C. Stress at a tension load of 666,536 lbs. is illustrated in Figs. 19A, 19B, and 19C. The red areas illustrated in Figs. 19A, 19B, and 19C show an excess of stress acting across the entire wall of the connection box representative of a failure condition.

Figs. 20A, 20B, and 20C are similar to Figs. 17A, 17B, and 17C, illustrating low stress distribution in a 7½-inch by 4⅞-inch JWSC connection with an interference of 0.010 inch in the engaged metal-to-metal seal area. The metal-to-metal seal area is also a 15°taper; however, the connection is otherwise similar to the connection illustrated in Figs. 15 and 16. Fig. 20A is a quarter-sectional view of the stresses induced in the connection, as indicated by the different coloration located at the stressed points of the engaged components. Fig. 20B is an enlarged view of Fig. 20A, and Fig. 20C is an enlarged section of the engaged connector of the invention.

Figs. 21A, 21B, and 21C illustrate the stresses induced in the connection of Fig. 20A when the force engaging the collar nose and pin shoulder surfaces is 733,160 lbs. As may be noted in Fig. 21C by minimal presence of the maximum stresses (indicated in red), increasing the connection box diameter by ¼ inch appreciably increases the structural strength of the box, permitting additional tension to be applied to the connection without danger of failure.

Figs. 22A, 22B, and 22C illustrate stress distribution on a connector having a 7.497-inch outside diameter (OOtj), 4.764-inch inside diameter (10tj) with a preload interference of 0.010 inch.

Figs. 23A, 23B, and 23C illustrate the connector of Figs. 22A, 22B, and 22C with an applied tension load of 844,224 lbs. As may be noted in Fig. 23A, the tension load exceeds the maximum rating for the drill pipe body; the connector, however, is within permitted loading limits. The groove for an elastomeric seal ring is not illustrated in the analysis of Figs. 22A, 22B, and 22C.

Fig. 24 is a table illustrating dimensions and ratings for different pipe connections. In a connection according to the present invention, the torque required to make up the lock collar to a pipe having a 5½-inch outside diameter with a 7½-inch tool joint OD; 4.1875-inch ID, with a shoulder diameter of 6.349 inches and a minimum shoulder length of 0.739 inches; a thread length of 3 inches and a thread pitch diameter of 6.586 inches is 4,816 ft-lbs. By comparison, the make-up torque required to secure

a conventional tool joint having a similar outside box diameter is 50,000 ft-lbs. Thus, it may be appreciated that the torque required to secure a connection of the present invention is much less than that required to secure a corresponding conventional tool joint connection, and accordingly, relatively small power tongs may be employed to engage the connection of the present invention.

It is desired that the outside diameter of the connector of the present invention be made as small as possible to enhance the drilling characteristics of the drill string. To this end, where a tool joint is welded onto the drill pipe tube, the tube may advantageously be internally upset to thereby decrease the outside diameter of the tool joint. Additionally, the steel used for the tool joint may be made of 135,000 psi material to permit a reduction in the outside diameter of the tool joint.

While specific examples of the connector of the present invention have been described herein in detail, it will be appreciated that various modifications of the connector may be made without departing from the scope of the invention. Thus, the elastomeric seal ring described need not be included in the connector where the metal-to-metal seal provides adequate sealing. The connector may also be employed to join pipe sections other than drill pipe joints. The threads of the lock collar and box may be right-hand threads where the drilling operation does not impose a risk of backing off the connection during right-hand drill string rotation. The connector may also be advantageously used for only one or a few connections in an otherwise conventional string of rotary shouldered pipe connections. Accordingly, it is intended that the invention be limited only by the scope and spirit of the appended claims rather than by the specific examples described in the specification and drawings.

What is claimed is:

1. A connector for securing together and sealing the ends of tubular bodies, comprising:

a box connection carried at the end of an axially extending, first tubular body;

a pin connection carried at the end of an axially extending, second tubular body, said pin connection being receivable within said box connection;

a lock collar having the threaded area threadably engageable between said box and said pin connections for securing said box and pin connections together to prevent axial separation between said box and pin connections;

a box rotation lock carried by said box connection;

a pin rotation lock carried by said pin connection, said box and pin rotation locks being engageable when said pin connection is received in said box connection for preventing relative rotation between said pin and said box connections; and

a metal pin seal and a metal box seal for forming a pressure seal between said pin and box connection when said pin connection is received within said box connection, said metal pin and metal box seal comprising engageable axially tapering annular sealing surfaces formed on said pin connection and said box connection.

2. A connector as defined in Claim 1 wherein said box is internally threaded and said lock collar is externally threaded whereby said lock collar may be threadably engaged within said box for holding said pin seal engaged with said box seal.

3. A connector as defined in Claim 2 wherein said pin connection includes an enlarged annular shoulder extending radially from said second tubular body for limiting the axial movement of said lock collar relative to said second tubular body whereby rotary motion of said lock collar threadedly engaging said box advances said pin connection into said box connection.

4. A connector as defined in Claim 1, further including an annular, elastomeric seal disposed between said pin and box connections.

5. A connector as defined in Claim 4 wherein said elastomeric seal is disposed in a tapering, annular sealing surface of said pin or said box.

6. A connector as defined in Claim 4 wherein said elastomeric seal is disposed in an annular, cylindrical space defined between said pin and box connections.

7. A connector as defined in Claim 1 wherein said box rotation lock and said pin rotation lock each comprise axially extending radial ribs and recesses forming a spline connection in which ridges and recesses of the engaged pin and box connections register to prevent relative rotational movement between said pin connection and said box connection.

8. A connector as defined in Claim 1 wherein said lock collar includes a tool engagement surface extending axially away from said threaded area of said lock collar whereby said lock collar may be engaged and rotated by a tool to engage and disengage said lock collar and said box connection.

9. A connector as defined in Claim 8 wherein the external diameter of said tool engagement surface is smaller than the external diameter of said box connection.

10. A connector as defined in Claim 1 wherein said lock collar is provided with left-handed threads whereby said lock collar is advanced into said box connection by counterclockwise rotation.

11. A connector as defined in Claim 1 wherein said tapering annular sealing surfaces are inclined relative to a common central axis of said pin connection and said box connection by 5° to 45°.

12. A connector as defined in Claim 1 wherein said metal pin seal and metal box seal are respectively inclined at an angle of between 15° and 30° relative to a central axis of said pin connection and said box connection.

13. A connector as defined in Claim 1 wherein said lock collar is comprised of multiple components secured together with alignment and retention structure whereby said lock collar may be assembled with said connection after said pin connector is connected to said second tubular body.

14. A connector as defined in Claim 1, further comprising a threaded tool joint connection secured to an end opposite said pin connection on said second tubular body for forming a top drive subassembly.

15. A string of drill pipe for drilling a well bore, said string being comprised of a plurality of engaged tubular pipe sections, each pipe section having a box end connection formed at one axial end and a pin end connection formed at its other axial end, said pin and box connections of adjoining pipe sections being engageable with each other to form an elongate string, each of said connections of said string comprising:

a box connection carried at the end of an axially extending, first tubular body;

a pin connection carried at the end of an axially extending, second tubular body, said pin connection being receivable within said box connection;

a lock collar having a threaded area threadably engageable between said box and said pin connections for securing said box and pin connections together to prevent axial separation between said box and pin connections;

a box rotation lock carried by said box connection;

a pin rotation lock carried by said pin connection, said box and pin rotation locks being engageable when said pin connection is received in said box connection for preventing relative rotation between said pin and said box connection; and

a metal pin seal and a metal box seal for forming a pressure seal between said pin and box connection when said pin connection is received within said box connection, said metal pin and metal box seal comprising engageable axially tapering annular sealing surfaces formed on said pin connection and said box connection.

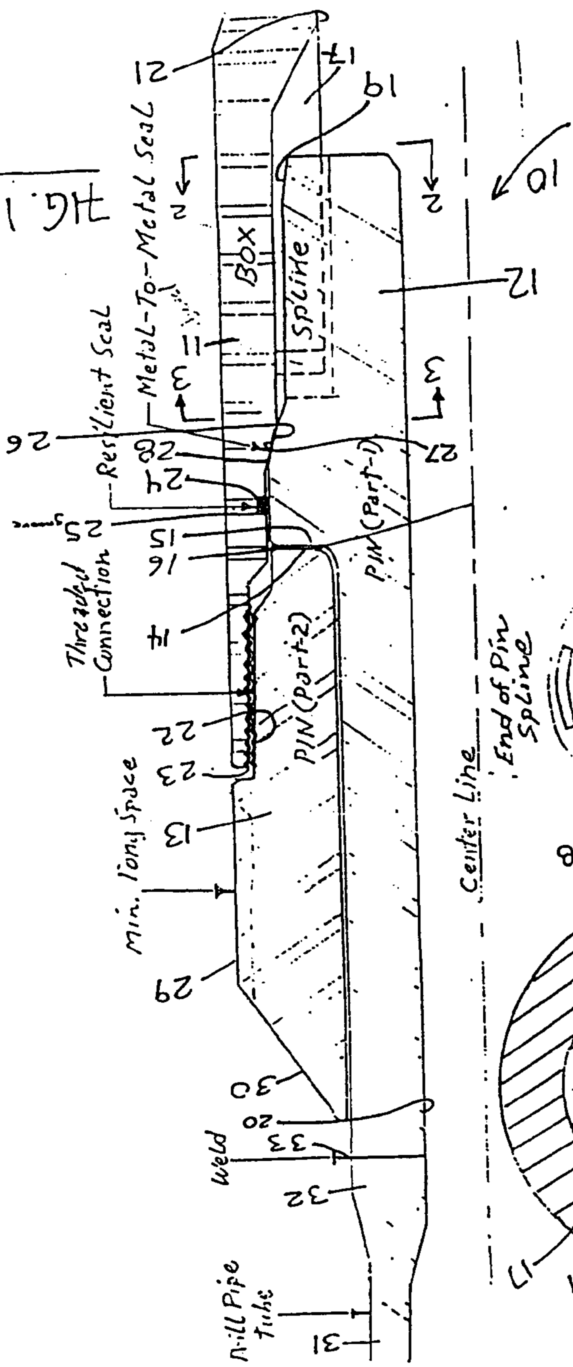


FIG. 1

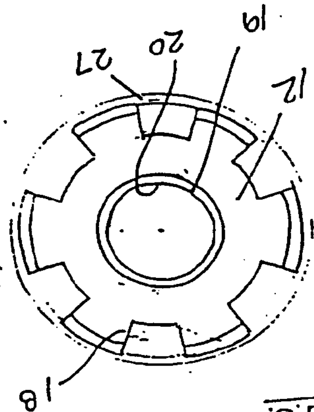


FIG. 2

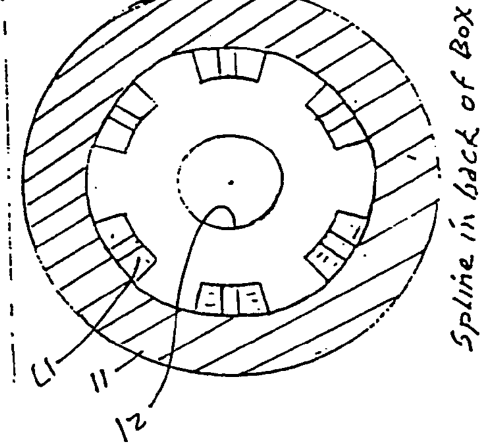


FIG. 3

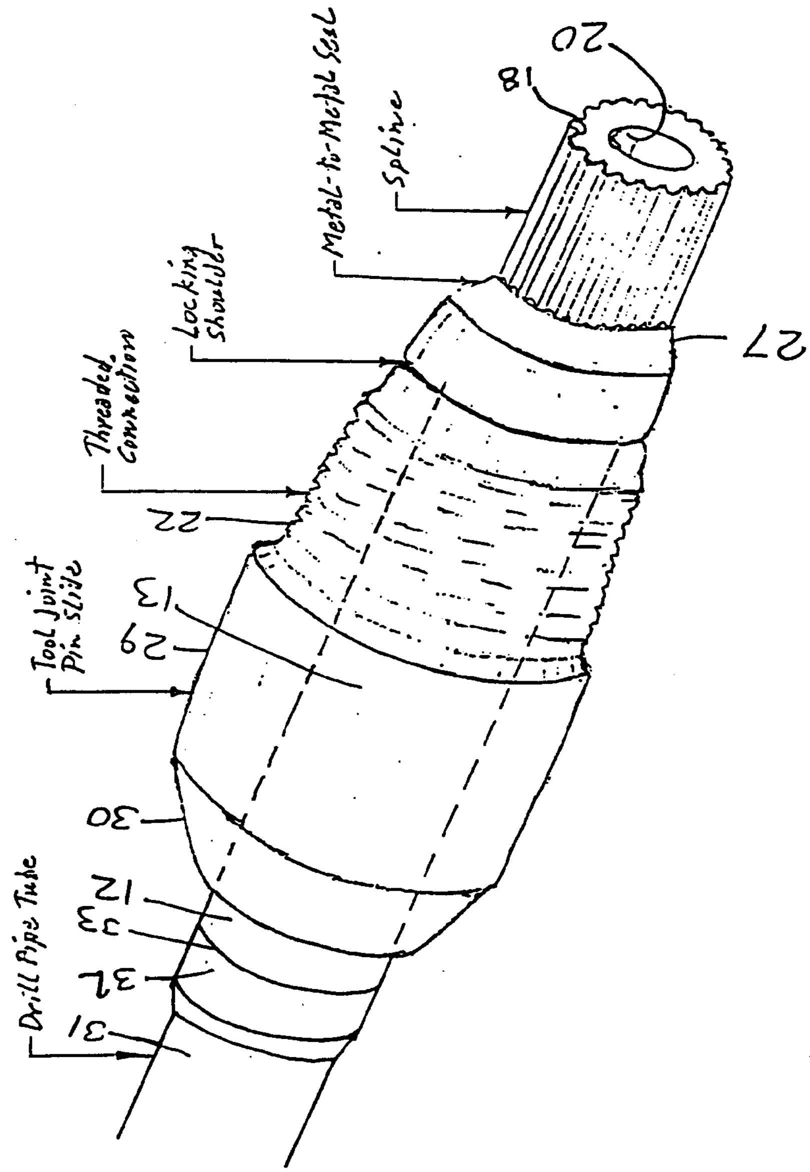

Drill Pipe Tube
31
32
33
12
30
Tool Joint Pin Side
29
13
22
Threaded Connection
Locking Shoulder
27
Metal-to-Metal Seal
Spline
18
20

FIG. 4

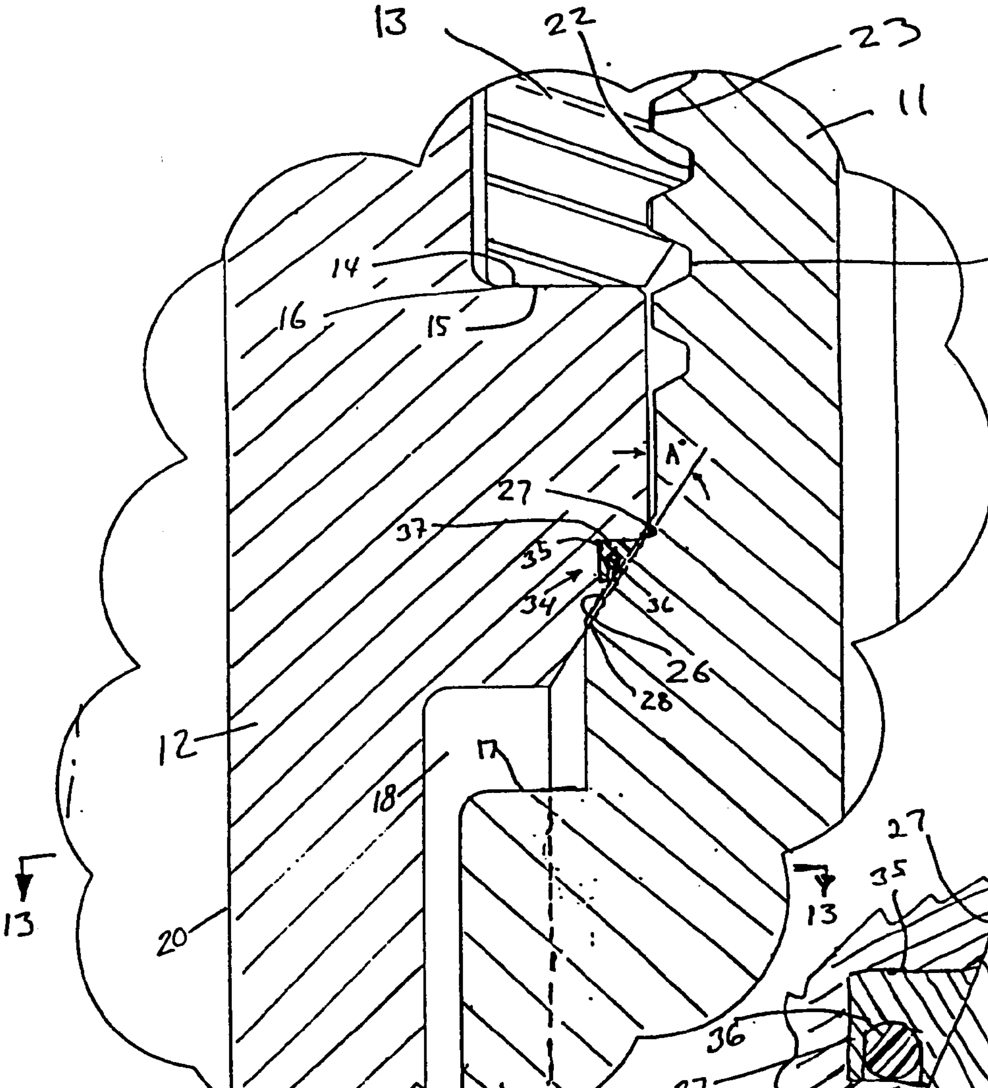

13
22
23
11
39
14
16
15
A°
27
37
35
34
36
26
28
12
18
17
13
13
20

FIG. 5.

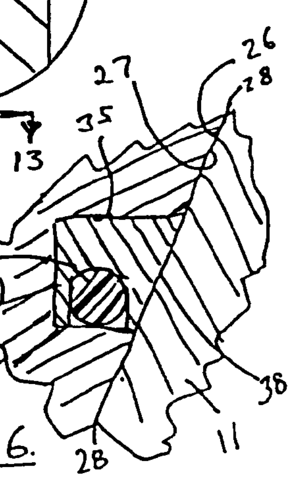

26
27
28
35
36
37
12
34
38
11
28

FIG. 6.

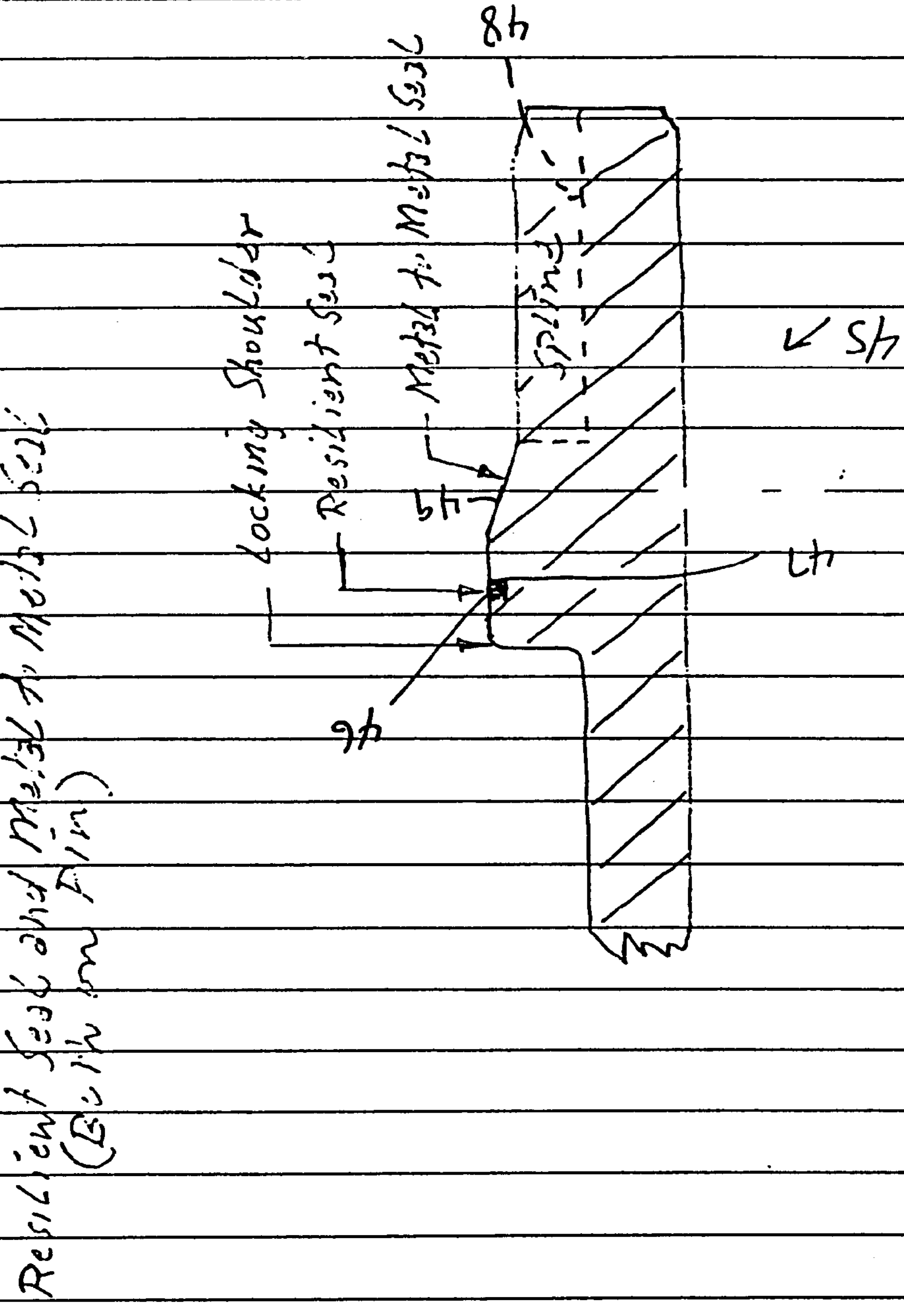

48
Metal to Metal Seal
Resilient Seal
Locking Shoulder
49
47
46
45
Resilient Seal and Metal to Metal Seal

FIG. 7

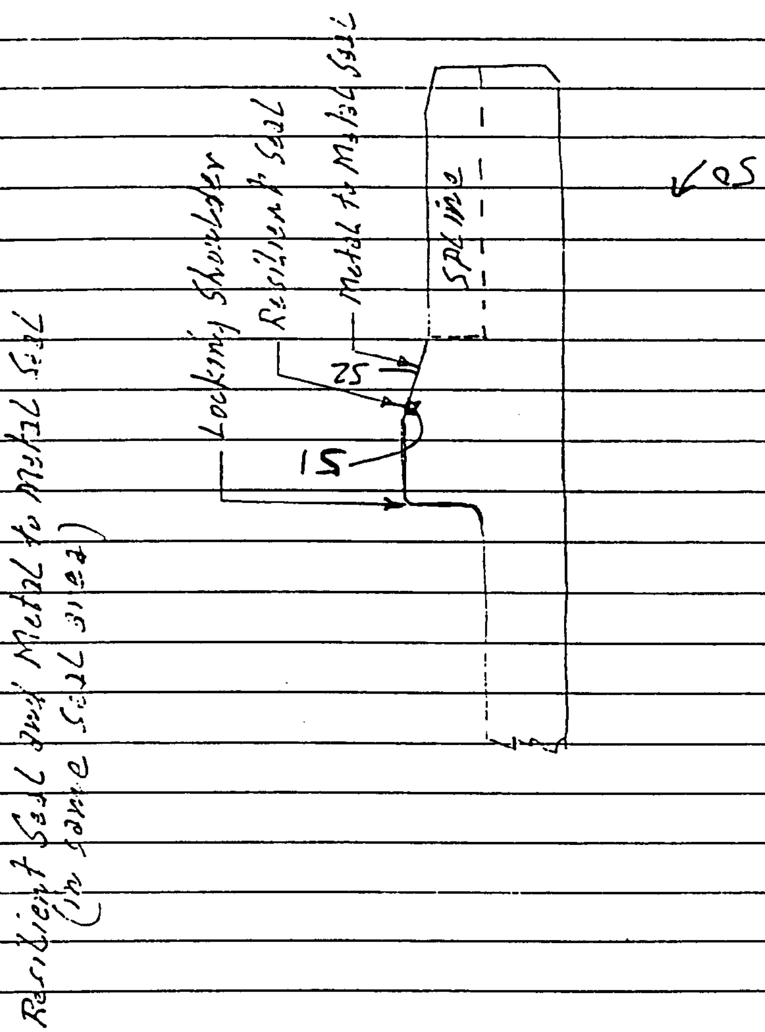

Resilient Seal and Metal to Metal Seal
(in same seal area)
Locking Shoulder
Resilient Seal
Metal to Metal Seal
Spline
51
52
50

FIG. 8.

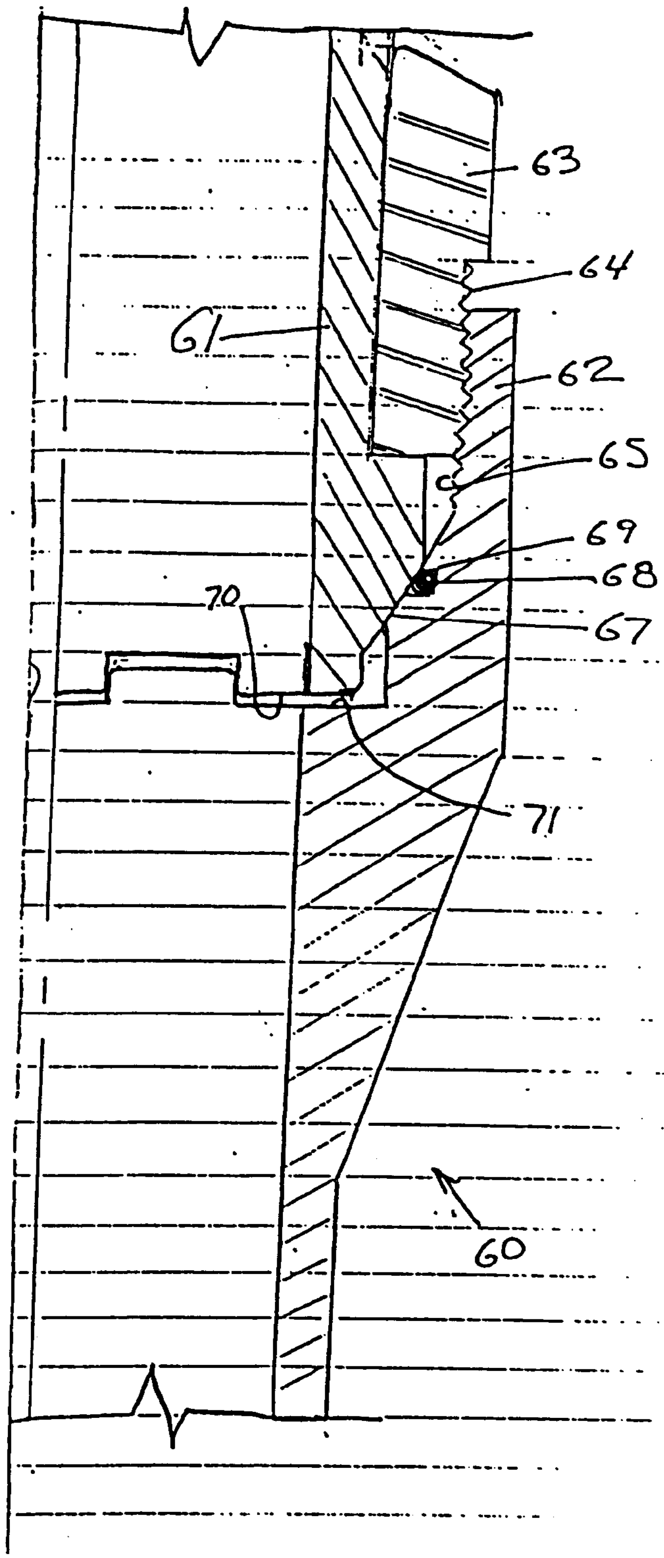


FIG. 9.

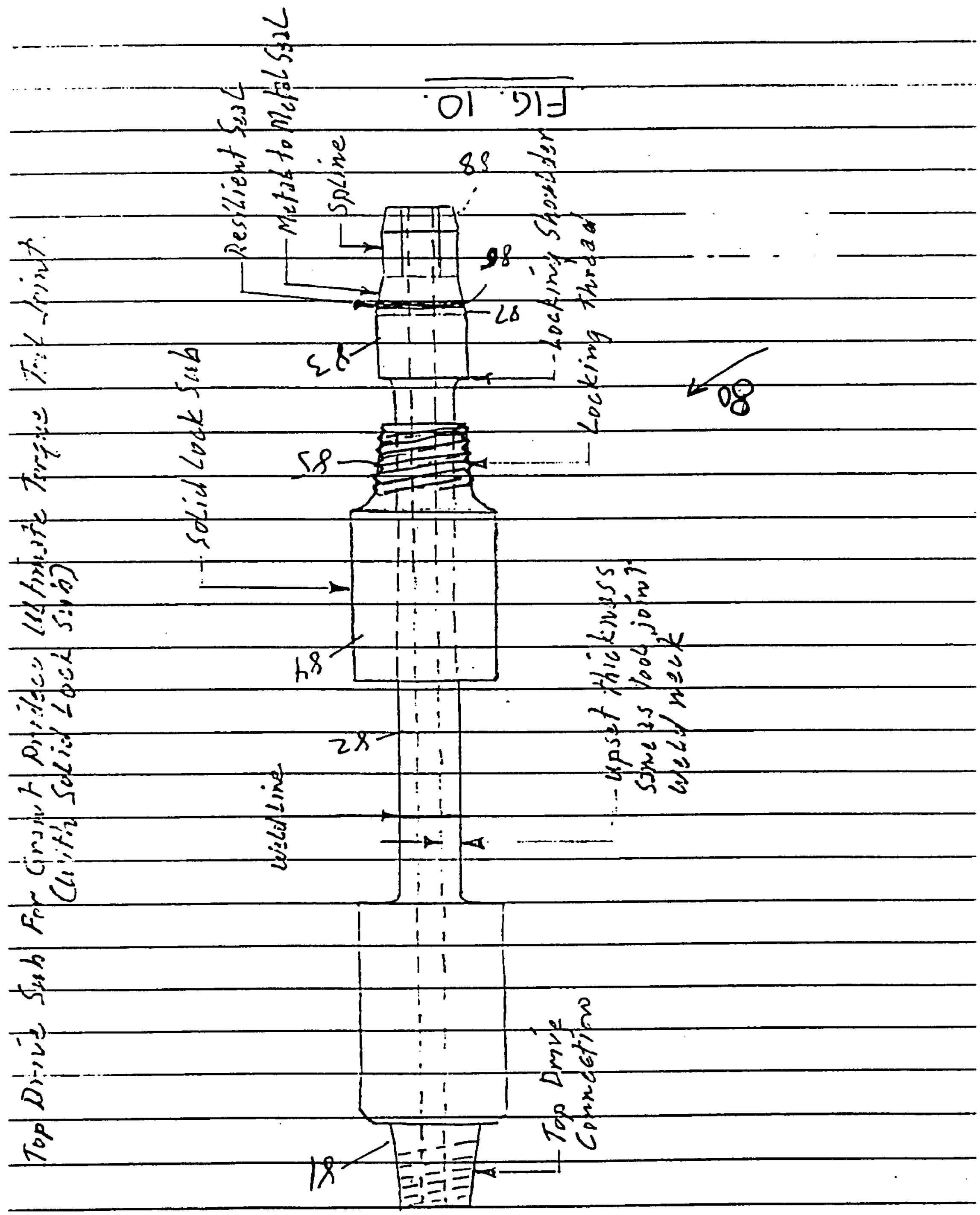

Resilient Seal
Metal to Metal Seal
Spline
88
86
87
Locking Shoulder
Locking Thread
83
80
85
Solid Lock Sub
84
82
Weld Line
Upset thickness same as tool joint weld neck
Top Drive Connection
81

FIG. 10.

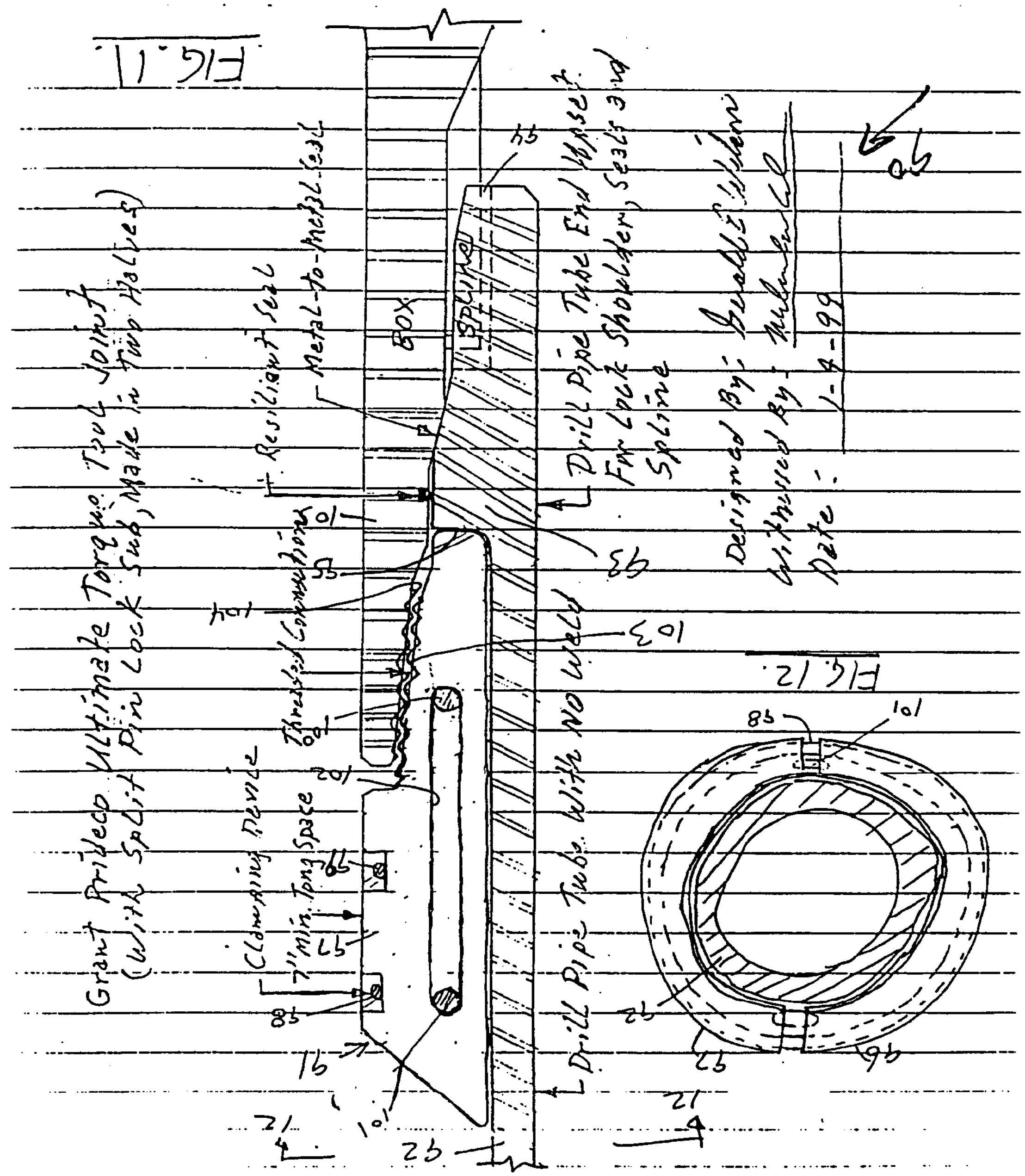

Grant Prideco Ultimate Torque Tool Joint
(With Split Pin Lock Sub, Made in Two Halves)
Resilient Seal
Metal-to-Metal Seal
BOX
Spline
Threaded Connections
Clamping Device
7" Min. Tong Space
Drill Pipe Tube End Upset For Lock Shoulder, Seals and Spline
Drill Pipe Tube With NO Weld
Designed By:
Witnessed By:
Date: 1-4-99
90
95
10
104
103
100
102
99
97
98
91
101
92
12
96

FIG. 11

FIG. 12

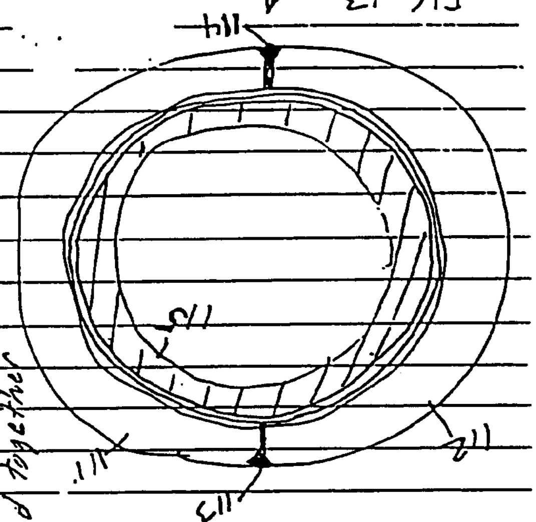

110
111
112
113
114

FIG. 13

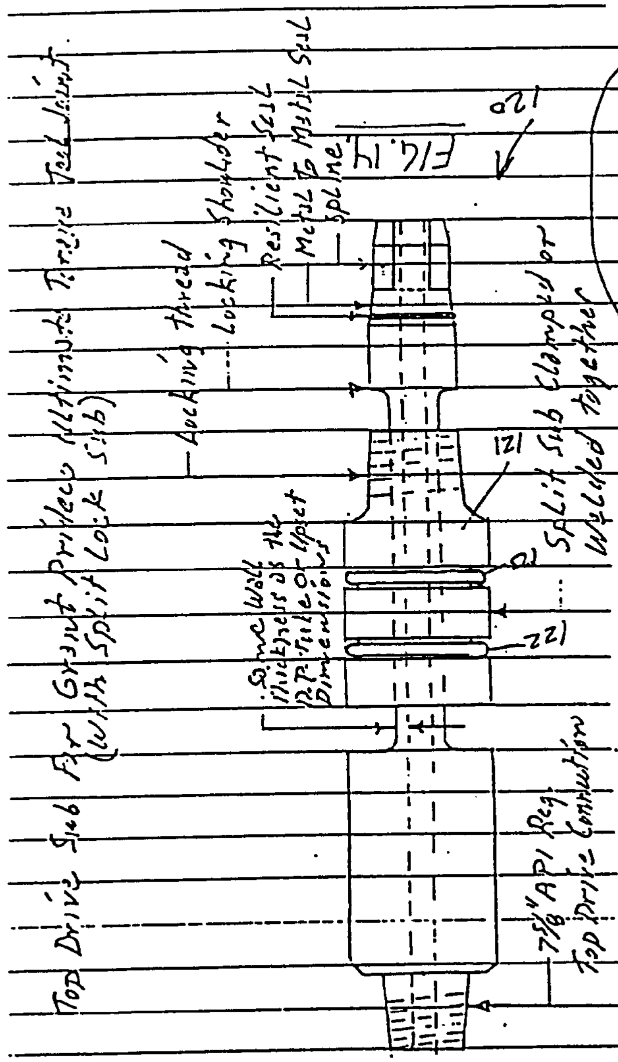
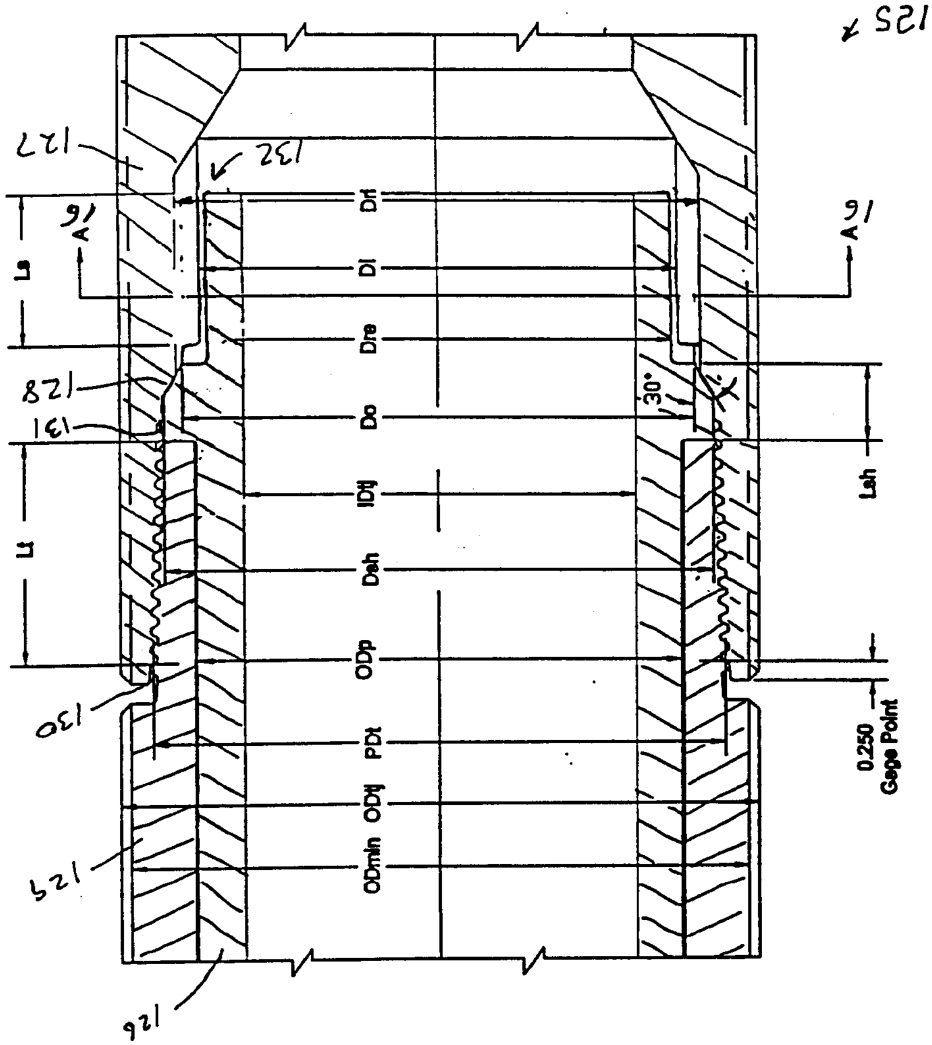

Top Drive Sub For Grant Prideco Ultimate Torque Tool Joint
(With Split Lock Sub)
Locking thread
Locking Shoulder
Resilient Seal
Metal to Metal Seal
Spline
120
121
122
Split Sub Clamped or Welded together
Same Wall thickness as the D.P. Tube or Upset Dimensions
7 5/8" API Reg Top Drive Connection

FIG. 14

FIG 15



Notes:
1. Type of Spline: 30° pressure angle, fillet root, side fit.
2. PAC thread form, 0.75 in/ft taper.

Section A - A

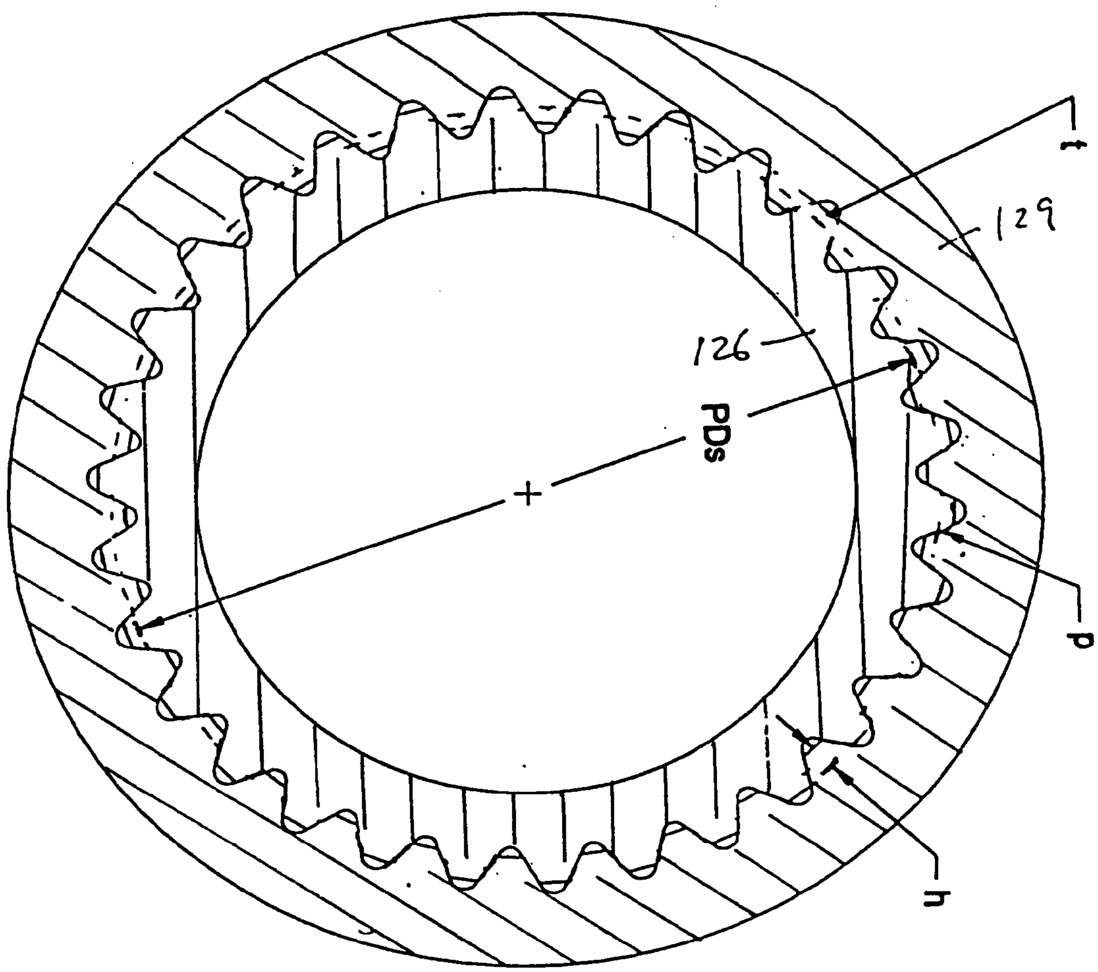


FIG 16


15° taper
ANSYS 5.5.1
MAR 25 1999
15:24:42
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NODAL SOLUTION
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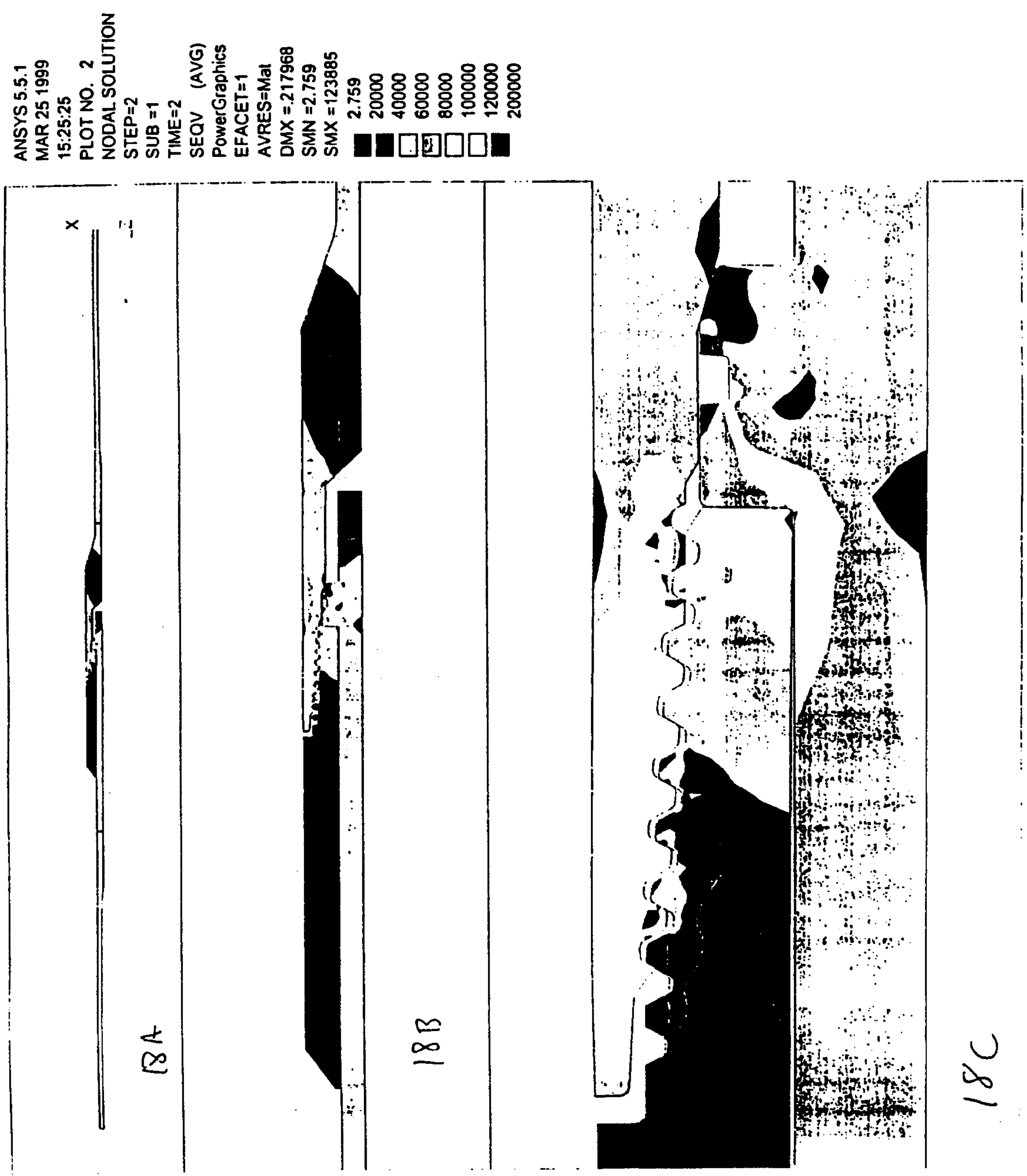
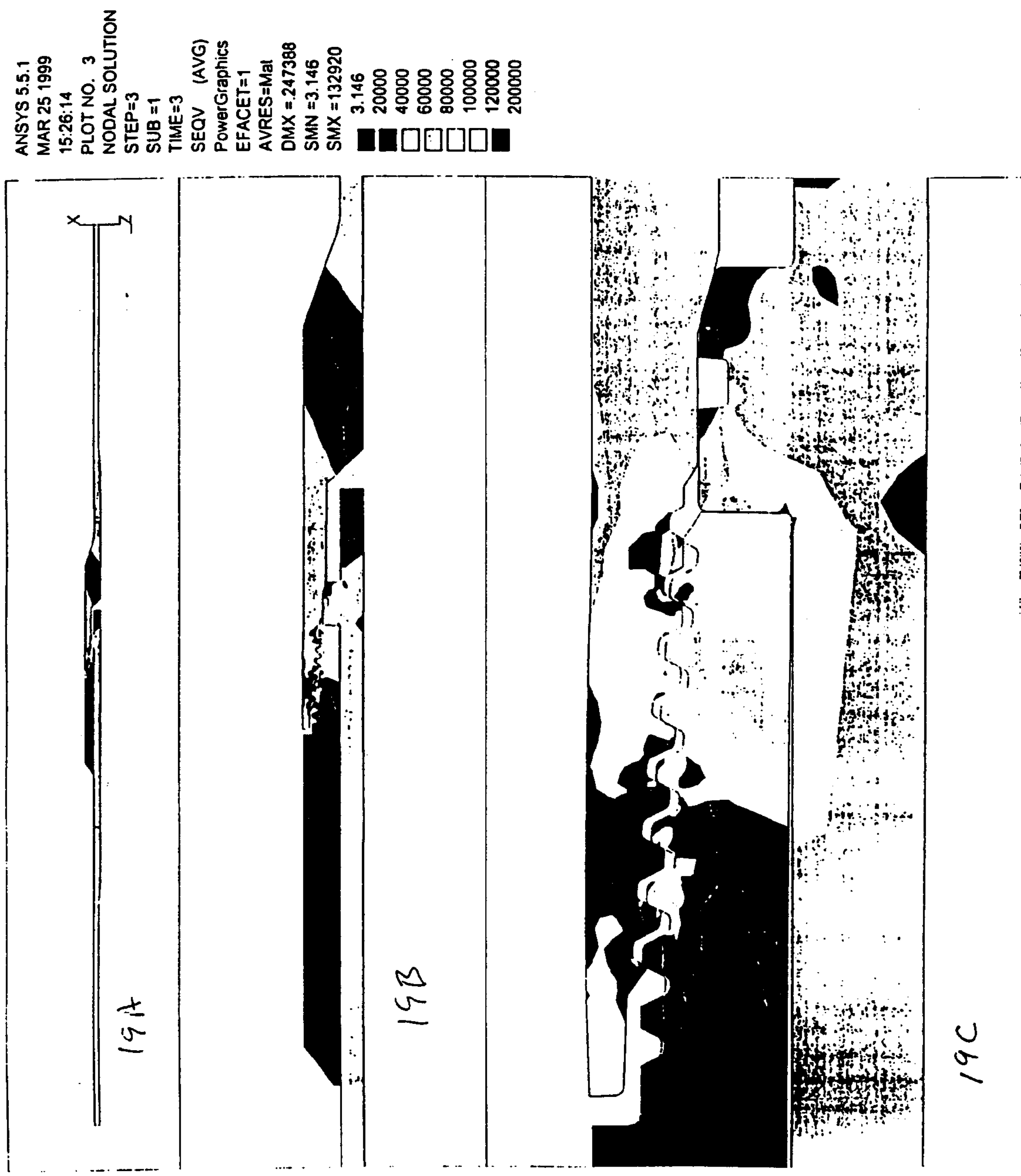
SUB =1
TIME=1
SEQV (AVG)
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.006689
SMN =.274E-07
SMX =98976
.274E-07
20000
40000
60000
80000
100000
120000
200000
17A
17B
17C
OD
ID

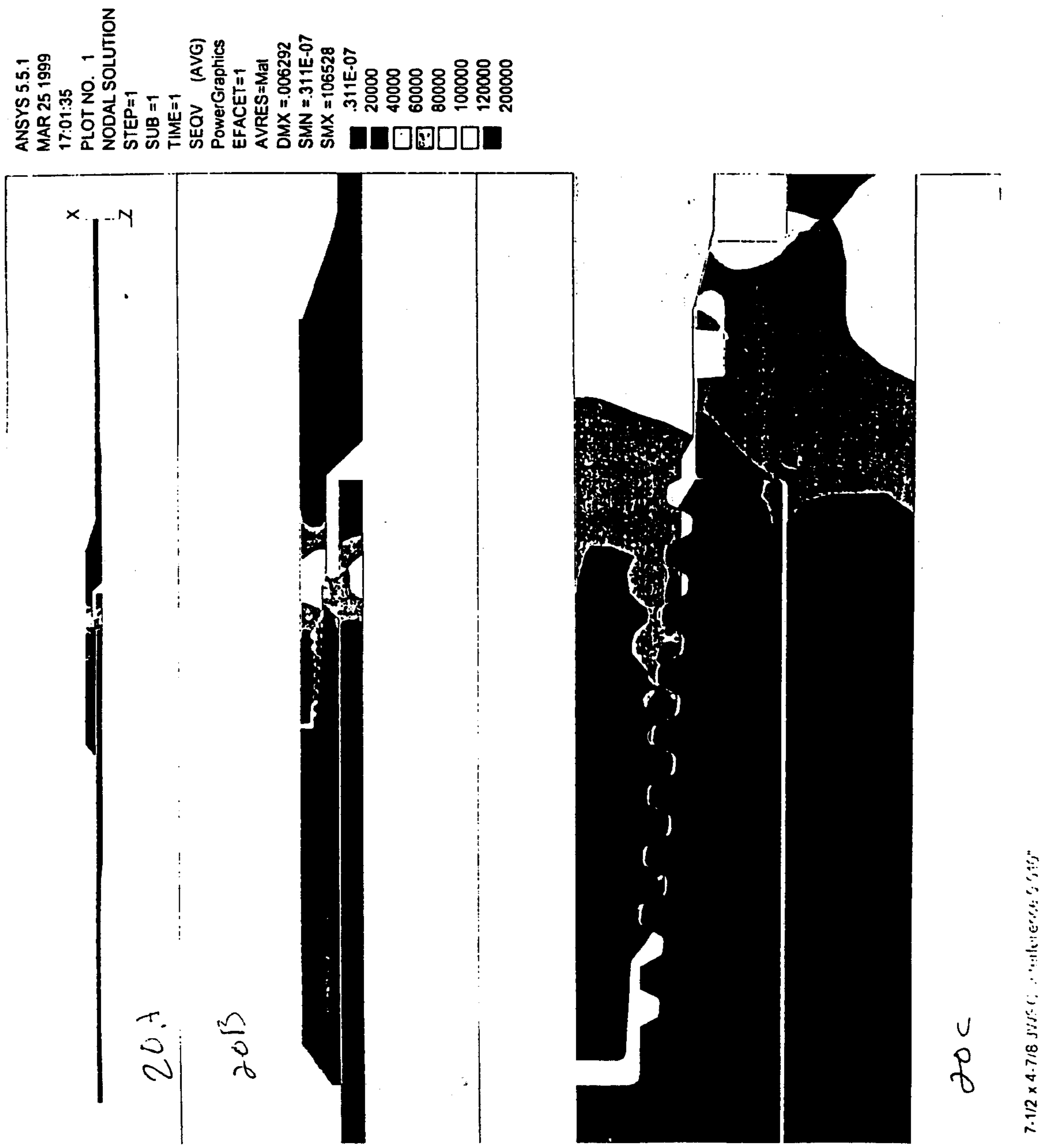


7-3/8x4-7/8 JWSC 0.010" interference, tension 600,000 lb



7-3/8x4-7/8 JWSC 0.010" interference, tension 666.536 lb

15° taper



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MAR 25 1999
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PowerGraphics
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SMX =106528
.311E-07
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40000
60000
80000
100000
120000
200000
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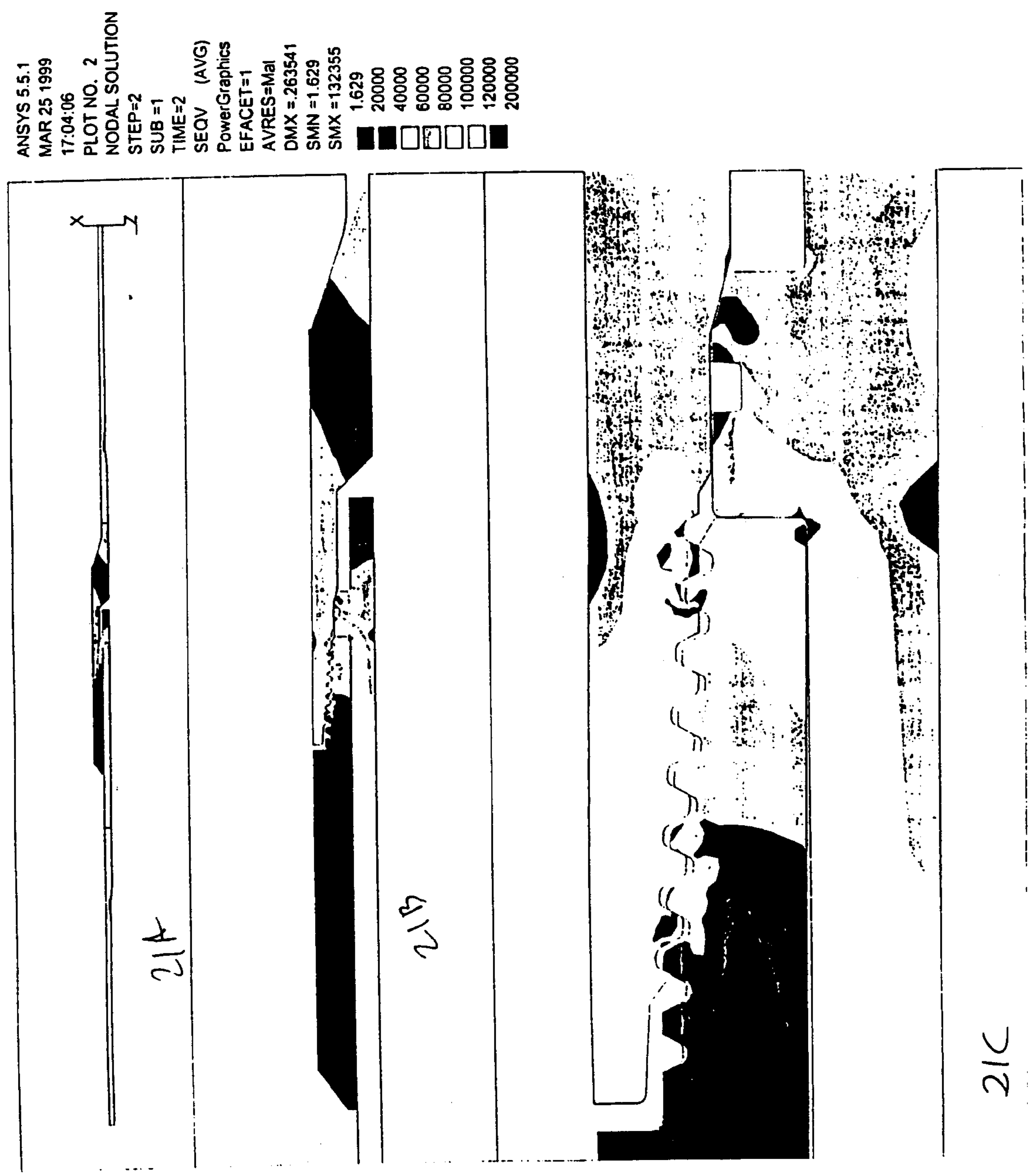
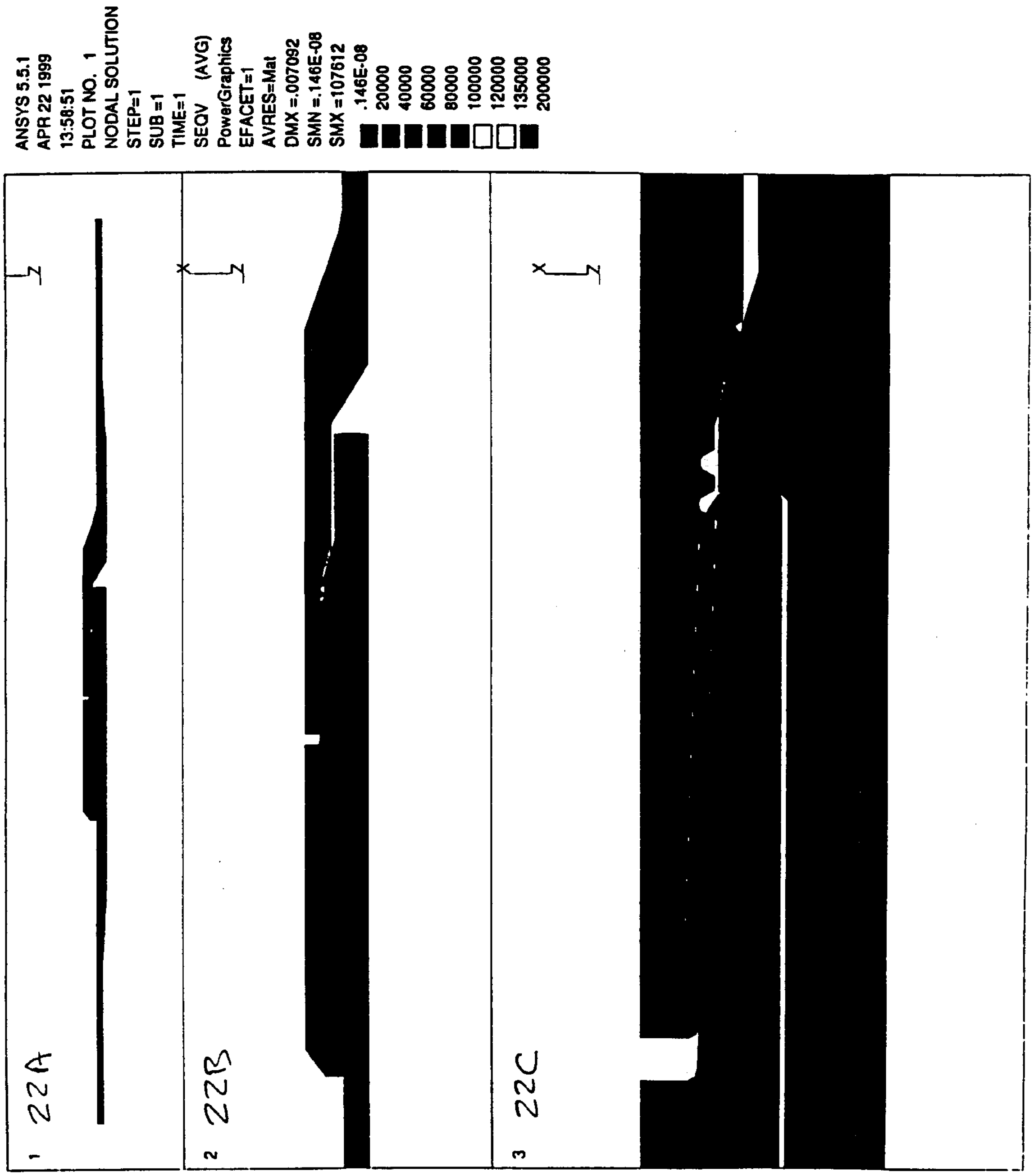
Z
20A
20B
20C

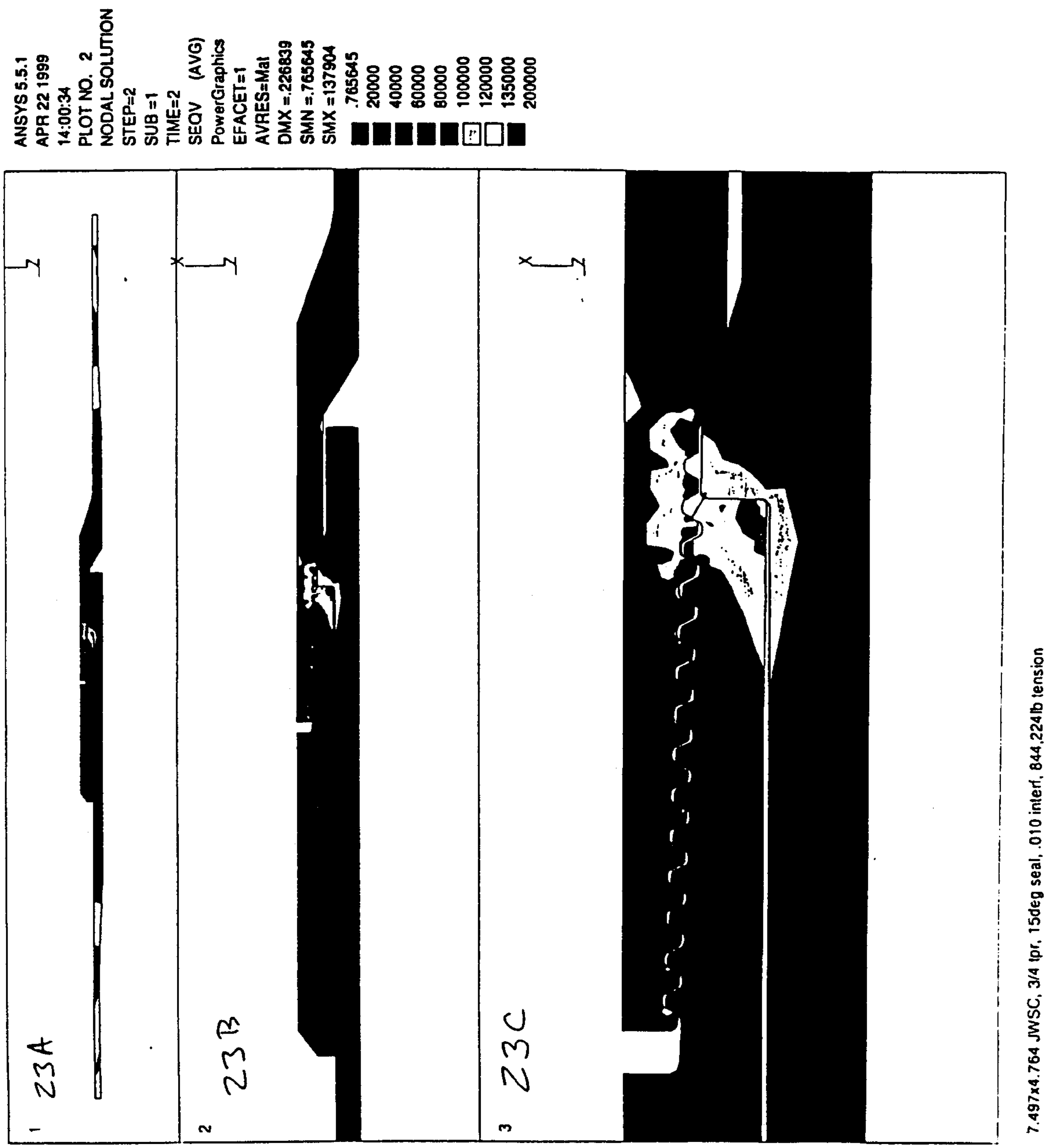


7-1/2 x 4-7/8 JWSC, interference 0.010", tension 733,190 lb

= 1.1 x tensil strength of pipe body



7.497x4.764 JWSC, 3/4 tpr, 15deg seal, .010 interf.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SMX =137904
.765645
20000
40000
60000
80000
100000
120000
135000
200000
1
23A
2
23B
3
23C
7.497x4.764 JWSC, 3/4 tpr, 15deg seal, .010 interf, 844,224lb tension

J. Wilson Spline Connection Calculations

Pipe						
Pipe OD, ODp (in)	5.500	5.500	5.875	5.875	6.625	6.625
Pipe ID, IDp (in)	4.778	4.670	5.153	5.045	5.965	5.901
Wall (in)	0.361	0.415	0.361	0.415	0.330	0.362
Tensile Strength (lb)	786,809	894,999	844,224	961,002	881,035	961,556
Torsional Strength (ft-lb)	91,278	101,833	105,489	117,915	127,044	137,330
Connection						
Tool Joint OD, ODtj (in)	7.375	7.500	7.750	7.875	8.500	8.500
Min. Tool Joint OD, ODmin (in)	7.114	7.258	7.495	7.643	8.164	8.258
Tool Joint ID, IDtj (in)	4.375	4.1875	4.750	4.5625	5.5625	5.500
Shoulder Diameter, Dsh (in)	6.268	6.349	6.644	6.726	7.345	7.397
Min. Shoulder Length, Lsh min (in)	0.659	0.739	0.657	0.738	0.605	0.655
Thread						
Thread Length, Lt (in)	3.000	3.000	3.000	3.000	3.000	3.000
Thread Pitch Diameter, PDt (in)	6.506	6.586	6.931	6.964	7.583	7.634
Thread Shear Strength (lb)	2,353,593	2,383,279	2,509,908	2,521,792	2,749,060	2,767,969
Make-up Torque (ft-lb)	4,771	4,816	5,060	5,086	5,553	5,581
Splines						
Number of Splines	28	28	30	30	34	34
Diametral Pitch, P	5	5	5	5	5	5
Change Factor, K	1.571	1.571	1.580	1.580	1.594	1.594
Actual Spline Length, Ls (in)	2.500	2.500	2.500	2.500	2.500	2.500
Circular Pitch, p	0.628	0.628	0.628	0.628	0.628	0.628
Spline Pitch Diameter, PDs (in)	5.600	5.600	6.000	6.000	6.800	6.800
Minor Diameter Ext., Dre (in)	5.240	5.240	5.640	5.640	6.440	6.440
Major Diameter Ext., Do (in)	5.800	5.800	6.200	6.200	7.000	7.000
Minor Diameter Int., Di (in)	5.400	5.400	5.800	5.800	6.600	6.600
Major Diameter Int., Dri (in)	5.960	5.960	6.360	6.360	7.160	7.160
Effective Spline Length, Le (in)	0.926	1.067	0.978	1.125	1.021	1.077
Spline Circular Thickness, t (in)	0.314	0.314	0.314	0.314	0.314	0.314
Depth of Engagement, h (in)	0.200	0.200	0.200	0.200	0.200	0.200
Shaft Torsional Strength (ft-lb)	94,267	108,590	113,622	130,738	150,945	159,319
Spline Shear Strength (ft-lb)	254,424	254,424	290,405	290,405	369,733	369,733
Spline Compr. Strength (ft-lb)	130,667	130,667	150,000	150,000	192,667	192,667
XT Connection T3 Value (ft-lb)	**82,990**	**91,949**	**93,361**	**103,562**	**114,309**	**116,140**

Input Data	
Pipe Ys (psi)	135,000
Tool Joint Ys (psi)	135,000
Weld Ys (psi)	100,000
Weld Safety Factor	1.1
Shoulder Preload (lb)	100,000
Wear Allowance on Dia. (in)	0.250
TPI	4
Thread Taper (in/ft)	0.75
Tread Height, Not Truncated (in)	0.216
Thread Height, Truncated (in)	0.093
Root Truncation (in)	0.058
Crest Truncation (in)	0.066
Width of Root (in)	0.067
Thread Angle (deg)	30
Friction Coefficient	0.08
Slide Clearance on Dia. (in)	0.031
Design Compressive Stress on Splines (psi)	40,000

Notes:
1. ID calculated based on weld strength.
2. Preload induces 0.010" interference on sealing of 5-7/8" 0.361" pipe.
3. Splines calculated based on Tool and Manufacturing Engineers Handbook.
4. XT Connection T3 Value calculated based on same OD & ID, and 120,000 psi Ys

FIG. 24.

AMM
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INTERNATIONAL SEARCH REPORT	International application No. PCT/US00/11578

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : F16L 19/00
US CL : 285/92,330,914,913,354
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 285/92,330,914,913,354

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 3,361,453 A (BROWN et al) 02 January 1968 (02-01-68), see locking collar 13, rotation lock 35,36, metal to metal seal 21,22 and o-ring seal 37 in fig. 8.	1-4,6-8,11-15 -------------------- 5,9
X	US 1,589,781 A (ANDERSON) 22 June 1926 (22-06-26), see locking collar 8, splines 11,12 and metal to metal seal 9,10.	1,8,10-12,14,15
Y	CA 687,376 A (WAGNER) 26 May 1964 (26-05-64), see o-ring seal 29 in the tapered seal surface.	5
Y	US 2,296,198 A (BOYNTON) 15 September 1942 (15-09-42), see tool engaging surface 3d or 3Ad on the coller 3 or 3A, respectively.	9

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

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